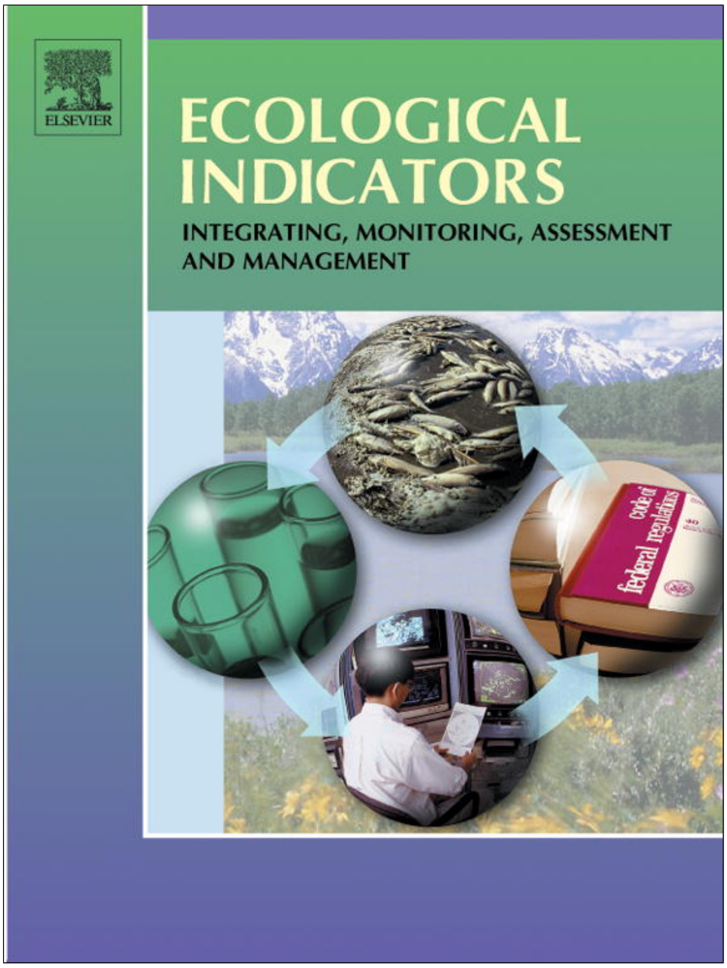
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Short communication

Carbon footprint of science: More than flying

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ABSTRACT

Previous efforts to evaluate the climate change impact of researchers have focused mainly on transport related impact of conference attendance, and infrastructure. Because these represent only a part of the activities involved in the science making process this short note presents the carbon footprint of a complete science making process of one specific case. Apart from presenting the total footprint, we evaluate the relative contribution of the different scientific activities, and quantify mitigating possibilities. The case PhD project had a carbon footprint of 21.5 t CO_2-eq (2.69 t CO_2-eq per peer-reviewed paper, 0.3 t CO_2-eq per citation and 5.4 t CO_2-eq per h-index unit at graduation) of which general mobility represents 75%. Conference attendance was responsible for 35% of the carbon footprint, whereas infrastructure related emissions showed to contribute 20% of the total impact. Videoconferencing could have reduced the climate change impact on this case PhD with up to 44%. Other emission reduction initiatives, such as using green electricity, reduction of energy consumption, and promoting commuting by bicycle, could have triggered a reduction of 14% in this case study. This note fits in the movement of academics and universities willing to be green. The study confirms that researchers' mobility is the biggest contributor to his or her carbon footprint, but is not limited to conference attendance, showing the importance of considering all activities in the science making process.

1. Introduction

The environmental impact of frequent traveling by scientists has been recurrently criticized. For those occupied with ecology, environment and climate change the irony of the traveling behavior is often emphasized (Burke, 2010; Reay, 2003; Fox et al., 2009). Because individual mobility is highlighted as a significant contributor to climate change (Althaus, 2012) and the major part of the environmental impact of conferences is due to travel of participants (Bossdorf et al., 2010), flying to meetings to protect the environment sounds paradoxical indeed (Gremillet, 2008).

Conference attendance is only one of the activities that researchers perform. Office use and experiments require inputs such has heating, electricity, infrastructure and equipment which may trigger significant environmental impacts as well (Parsons, 2009). In fact, universities tend to take action to reduce their environmental impacts. Realizing the competitive advantage of carbon management they focus on their infrastructure to achieve campus-based emission reduction (Mascarelli, 2009).

In this short note we aim to present the carbon footprint of a complete science making process of one specific case, including experiments, desktop work and travel for field work, meetings and conferences, rather than limiting the discussion to the infrastructure and conference attendance of the researchers. Such impact assessment of a science-making process could (i) indicate what the total impact of scientific achievements is, (ii) evaluate the relative contribution of the different scientific activities, and (iii) identify and quantify mitigating possibilities.

2. Objective

As a case we quantify the total life cycle carbon footprint of the scientific activities (desktop work, fieldwork, meetings, and conferences) leading to a specific scientist's contribution: a PhD thesis. We evaluate the absolute and relative impact on climate change of the scientist's mobility, and the different reasons, as part of these activities.

Despite uncertainties regarding the potential greenhouse gas (GHG) emission savings of teleconferencing (Kitou and Horvath, 2008; Baliga et al., 2009), video telecommunicating is often advocated as an option to mitigate the impact of scientists (Dolci et al.,

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Table 1
Distances traveled (km) for different duties during a 4 years PhD study per transportation mode.

	Conferences	Meetings	Academic tasks	Commuting
Car	424.2	3419	973.6	
Bus	16.4	894.4		
Long distance train	967.4		9452.1	
Regional train	463	98.2	130.9	
Intercontinental flight	53,358	10,844.2	26,824	
Continental flight	9343.4	10,658.3	13,456	
Bicycle				6384

2011; Reay, 2003). Since the importance of this carbon benefit is unknown, we estimate the influence of opting for videoconferencing on the carbon footprint of the PhD thesis.

Further we evaluate the effect of several emission reduction initiatives ongoing at the case university (i.e. promoting commuting by bicycle, reduce energy consumption, consume only green electricity).

3. Materials and methods

The life-cycle assessment (LCA) procedure was used to evaluate the climate change impacts (carbon footprint in t CO_2-eq emissions) of all inputs involved in the production of the PhD thesis. The footprint was calculated according to the official ISO guidelines (ISO, 2006).

As a specific scientist's contribution case we chose a complete PhD project in Environmental Sciences at the University of Leuven (KU Leuven), Belgium. Being clearly delimited in time and related to the work of mainly one person, a PhD project is a well-defined functional unit.

Foreground data (Tables 1 and 2) were compiled from real activities of the PhD candidate, the ICT and the technical support services of the university. Energy implications of internet traffic were estimated from literature (Taylor and Koomey, 2008; EIA, 2001; Cisco, 2009). In order to cover all scopes of emissions recommended for carbon footprint assessments (Pandey et al., 2010; Peters, 2010), background data was included in the system inputs. These data were extracted from the EcoInvent life cycle inventory database. Analyses were performed in SimaPro® LCA software (Pré, the Netherlands) with the method IPCC 2007 GWP 100y.

Compared to the base scenario, four mitigation scenarios are calculated. First we evaluate the effect of substituting the travel for conferences and meetings with videoconferencing. Second we evaluate the effect of promoting commuting by bicycle. At the KU Leuven staff members are provided with a free bicycle and maintenance services to stimulate commuting by bicycle. As in the base scenario the PhD researcher always commuted by bicycle, the effect of this initiative is evaluated by calculating the impact for the case where the student would have commuted by car. The third scenario evaluates the effect of the KU Leuven decision to consume 100% green electricity. To evaluate the impact of this decision the complete electricity demand was modeled to be produced by hydroelectric, wind power or photovoltaic installations. The fourth scenario quantifies the effect of the reduction plan of energy consumption of the KU Leuven (i.e. 1% reduction in electricity consumption per year and 2.5% reduction in heat consumption per year).

4. Results and discussion

The case PhD project had a carbon footprint of 21.5 t CO_2-eq (2.69 t CO_2-eq per peer-reviewed paper, 0.3 t CO_2-eq per citation and 5.4 t CO_2-eq per h-index unit at graduation) (Fig. 1). The annual emission of 5.4 t CO_2-eq by the work of this Belgian PhD candidate represents 32% of the total annual footprint of an average Belgian citizen (Hertwich and Peters, 2009).

74% of the climate change impact (15.9 t CO_2-eq) is caused by mobility (mainly air travel, 95%). Office, internet and computer use represent 21% of the caused global warming potential. Office food, beverages, printing and the other inputs to the PhD cover the remaining 5% (Fig. 1). About half (46%) of the emissions triggered by mobility were due to conference attendance. The remainder was linked to project management meetings (21%) and to the research activities themselves (e.g. field work missions) (33%).

Although such assessment has not previously been published, studies have calculated the average emission profile of university systems. A comparison of the GHG emissions per graduate student of 4 years Master programs at the University of South Queensland and the New University of Lisbon, including infrastructure and commuting of students, indicates total emissions of 15.8 kg CO_2-eq and 7.6 kg CO_2-eq respectively (Parsons, 2009). This study further suggests a relatively low contribution of travel to the total emissions, and relatively high contribution of infrastructural inputs such as electricity for the buildings. The discrepancy can be explained by the different nature of undergraduate and graduate studies, compared to a doctoral program in which the students travel more and require an office.

Considering that academic tasks such as fieldwork require physical presence of the PhD candidate, we estimated the potential impact reductions by avoiding travel for meetings and conferences through multipoint videoconference attendance. Concerning meetings, it would have led to a total footprint of 18.7 t CO_2-eq (reduction of 13%). Attending the scientific conferences through video would have avoided 31% of the total GHG emissions. This means that reductions in mobility impacts through videoconferencing could have reduced the climate change impact on this case PhD with up to 44% (11.9 t CO_2-eq) (Fig. 1). Trends for emission reduction potential have been observed also for telework and for distance learning (Kitou and Horvath, 2008; Roy et al., 2008).

The contribution of face-by-face interactions at conferences and meetings to the final PhD, can be hardly quantified. Therefore it can be questioned if, doing all these interactions though videoconferencing would have resulted in the same PhD output in terms of quality or number of papers and citations. Presential interactions can be very important in setting up collaborations and creating scientific achievements. However, such effects are not taken into account in the presented comparison.

Taking a flight or not, by taking other means of transport or by videoconferencing, is often an individual choice. This could raise questions on the importance of individual choices on carbon footprints. Firstly, concerning the traveling emissions, one could argue that a plane, completely full or with empty seats, will fly, causing the same emissions, so not causing an emission reduction when deciding not taking a flight. Although the ongoing discussion on this topic brings many issues together (Hickman, 2013), we do not consider this as within the scope of this short note. Secondly, it is interesting to see how the reduction potential of individual choices

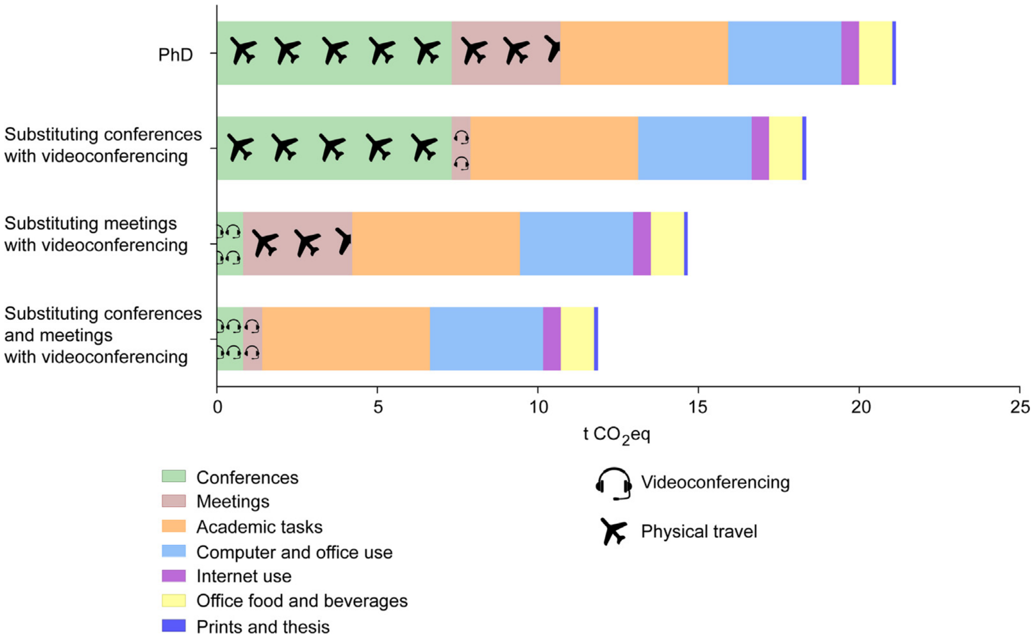

Fig. 1. Carbon footprint [t CO_2-eq] of a four year case PhD project and three scenarios where videoconferencing substitutes for physical traveling. Horizontal stacked bars show the total carbon footprint. The stacks show the share of different inputs to the PhD project.

compares to the reduction potential of institutional mitigation initiatives.

Of the four mitigation strategies calculated, two rely on the individual choice of the case researcher to mitigate, i.e. choosing to commute by bicycle (promoted by the institution) and choosing to videoconference. The other two mitigation initiatives (i.e. shifting to consuming green electricity and energy consumption reduction) are institutional. Evaluating the effect of these two latter initiatives shows that by shifting to green electricity a reduction in GHG emission of 8.5% could be achieved for the case PhD thesis. The initiatives for reducing the energy consumption could trigger a 0.27% reduction of GHG emissions (Fig. 2). On the other hand, the issues which depend (partially) on individual choices show, for the PhD thesis under research, a GHG emission reduction potential of 5% for commuting by bicycle (Fig. 2) and up to 43% when choosing to videoconference (Fig. 1).

The results of this case study indicate that individual choices have a large impact on the carbon footprint of scientific activities,

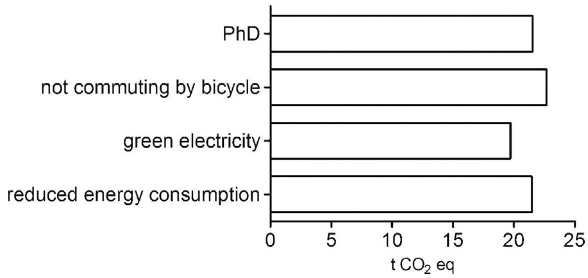

Fig. 2. Carbon footprint [t CO_2-eq] of a four year case PhD project, and three other scenarios in which (1) the student would not have commuted by bike, (2) all electricity consumed would have been 'green' electricity, and (3) the university energy consumption reduction plan was active.

Table 2
Inputs from in-office activities related to a 4 year PhD study.

		Amount	Unit
Printing		98.4	kg of paper
Thesis publication		9.2	kg of paper
Beverages		282.5	L
Natural gas (heating)		497.12	m^3
Electricity (lighting and non-informatic appliances)		3652.4	kWh
Laptop and LCD screen use		904	days
Laptop		1	unit
Internet		89	GB
LCD screen		1	Unit
Videoconferencing scenarios	Replacing conferences	133	GB
	Replacing meetings	95	GB
Not commuting by bicicle	Commuting by car	6384	km
Using green electricity	Hydro+	1217.5	kWh
	Solar+	1217.5	kWh
	Wind electricity	1217.5	kWh
Reduced energy consumption	Natural gas (heating)	489.6	m^3
	Electricity	3582.2	kWh

and universities. Therefore it is important, for universities willing to green their image, (1) not to focus solely on infrastructure and on-campus consumption and (2) to implement policies to influence the individual behavior and choices of their staff. This was also indicated for Belgian development cooperation institutes (Almeida et al., 2012). The promotion of commuting by bicycle at KU Leuven is a good example of such policy. It is recommended to explore and implement policies which could promote videoconferencing and reduce flying.

5. Conclusion

The case study shows that frequent traveling triggers a considerable impact. Conference attendance is responsible for 35% of the carbon footprint, whereas infrastructure related emissions showed to contribute 20% of the total impact. Further it is shown that videoconferencing could indeed significantly reduce the emissions. Other mitigation initiatives such as using green electricity, reduction of energy consumption and promoting commuting by bicycle, could trigger, for this case, an additional total reduction of 14%.

This note fits in the movement of academics and universities willing to be green. This issue has been approached from different angles and by different players in scientific journals. However, so far, calculations have been dimming onto infrastructure and polemic focuses on the traveling of academics. In such context it is important to have an assessment of the impact of the science-making process and an identification of the mayor contributors to the impact in the processes. Therefore we call for more exercises of this kind, in different disciplines and at the different levels of research outputs, individual scientists, and research institutes. How reductions should be organized belongs to a different discussion, and is not within the scope of this paper.

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